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(54) Electromagnetically operable valve

(57) The valve, for operation at high hydraulic pressures in which a cylindrical armature (10) surrounded by a hydraulic fluid is longitudinally displaceably mounted in a tubular guide (12, 13, 14) serving as a support for a magnetizing coil (15), is arranged to interact with a magnet yoke (16) and carries an actuating member (8, 9) for a valve element (1). In order to provide an accurately defined permanent flow gap for the hydraulic fluid between the guide and the armature, the latter is provided with spacedly disposed pouches in its peripheral surface, each non-rotatably accommodating a single ball (20, 21) projecting beyond said surface and being arranged to slide on the internal surface of the guide. The latter preferably comprises two soft iron end portions (12, 14) welded to opposite ends of a non-magnetizable stainless steel mid-portion (13). Advantageously, the armature's and the yoke's end faces which in operation contact each other are provided with means (25, 26 and, respectively, 27) to inhibit the end faces from sticking to one another.

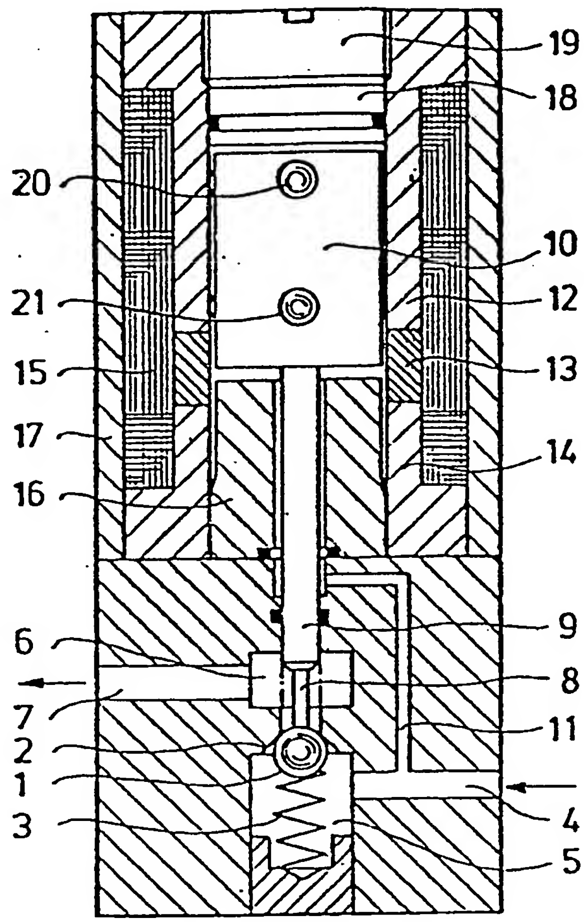

Fig.1

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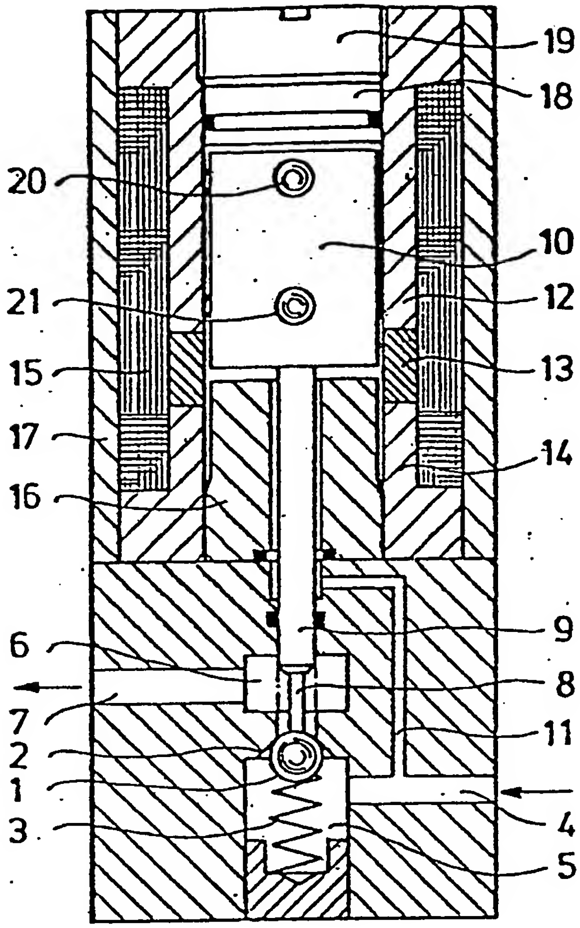


Fig.1

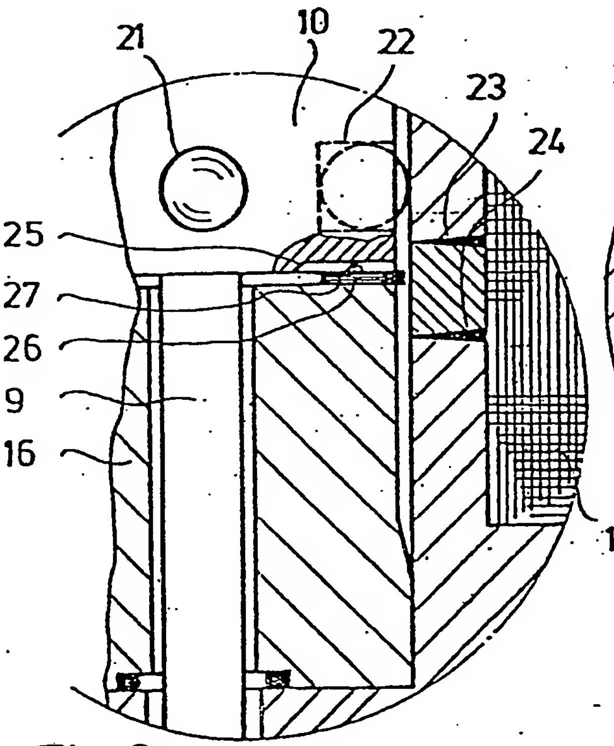
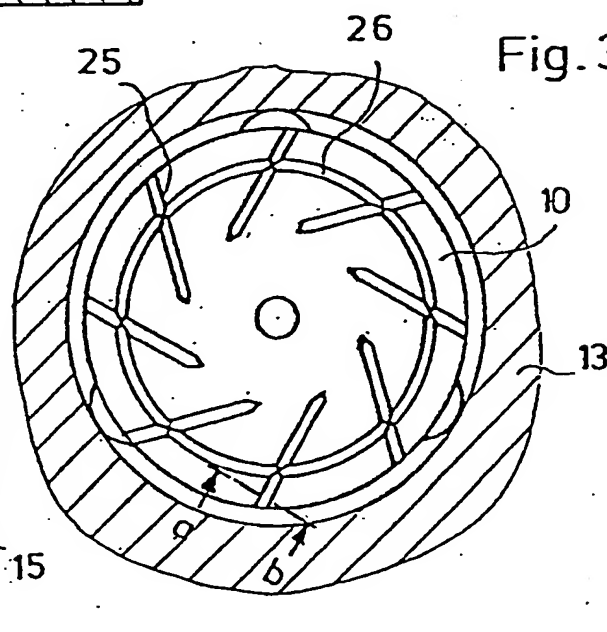


Fig.2

Fig. 3



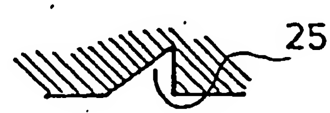


Fig. 4

SPECIFICATION

An electromagnetically operable valve

This invention relates to an electromagnetically operable valve, in which a roller-shaped magnet armature circumcirculated by a hydraulic fluid is longitudinally displaceably mounted in a tubular guide which also serves as a support for a magnetizing coil, is arranged to interact with a plug-shaped magnet yoke also disposed in the tubular guide, and in which the armature carries at its end face closest to the yoke an actuating member for a valve-closing element.

It is an aim of the invention to provide a valve of this kind the whole electromagnet part of which is constructed in such a way that the valve can be used to cope with high hydraulic pressures, for example approximately 630 bar, and that the ratio of magnetic energy produced by the electromagnet to its volume should be particularly high, thus rendering a space-saving construction of such a high-pressure hydraulic valve possible.

Accordingly, the invention is directed to an electromagnetically operable valve including a roller-shaped magnet armature circumcirculated by a hydraulic fluid, the armature

a) being longitudinally displaceably mounted in a tubular guide which also serves as a support for a magnetizing coil,

b) being arranged to interact with a plug-shaped magnet yoke also disposed in the guide, and

c) carrying at its end face closest to the yoke an actuating member for a valve-closing element,

in which the armature is provided with spacedly disposed pouches extending inwardly from its peripheral surface and each accommodating a single ball projecting beyond the peripheral surface and being arranged to slide, when the armature is operationally displaced in the guide, on the internal surface thereof. Although it is feasible to use magnetizable balls it is preferable, for reasons to be explained later, to use balls — similar to those of ball bearings — which are non-magnetizable.

It should be mentioned in this connection that it is already known from the published German Patent Application No. 28 23 257 to support a substantially roller-shaped armature of an electromagnetically operable valve by means of balls. However, a disadvantage of this known valve is that the balls are arranged like complete ball and cage assemblies — as in a typical ball bearing — and disposed in annular grooves of the armature, the grooves being considerably wider than the diameter of the ball bearing balls — the reason being to render it possible for the balls to really roll in the longitudinal direction of the armature when in operation the latter is longitudinally displaced. Further, hydraulic fluid does not circulate around the armature of the valve described in the aforementioned Application which, moreover, does not indicate, not even by implication, any means by which such a construction could possibly be used in the case of particularly high hydraulic pressures. A further disadvantage of the known valve is the use of the wide annular grooves which cause a considerable reduction of the magnetic flux into the armature — which is not acceptable in connection with a high-pressure valve of the kind with which the present invention is concerned. Finally, in view of the use of ball bearing cages and radial walls for separating the balls in the known valve its manufacture is comparatively expensive.

In contrast thereto, the present invention dispenses *ab initio* with the use of ball bearings as conventionally understood. The arrangement of single balls in respective individual pouches of the armature impedes rotation of the balls. It is easily evident that as a result of using single balls as large a surface as possible of the armature is available for the lines of magnetic flux to pass therethrough and thus for its magnetic induction.

The tubular guide preferably comprises a mid-portion of non-magnetizable stainless steel surrounding the operating air gap between the armature and the yoke, and two soft iron end portions respectively welded to the two end faces of the mid-portion. This division of the guide into three tube portions welded together is known *per se* from the German Patent Specification No. 26 28 190. However, it is not evident from this Specification that this, substantially casually referred to, construction is suitable — as has surprisingly been found — to withstand the high pressures of, for example 630 bar to which the tubular armature guide is subjected in a high-pressure valve according to the present invention.

It is also advantageous if those end faces of the armature and the yoke that in operation contact each other are provided, as known *per se*, with means for preventing, or at least inhibiting, the armature from sticking to the yoke. Such means may comprise a non-magnetic flat ring on the end face of the yoke and at least one annular and a number of, at least substantially, radial grooves in the end face of the armature. In this case, the cross-section of the radial grooves is preferably asymmetrical.

It has also been found that the armature, in a valve constructed according to the invention, rotates very slightly in the course of its longitudinal displacement. An advantage of these rotary motions is that during the working life of the guide longitudinal indentations are hardly likely to be formed in its internal surface. As a result of providing the end face of the armature with at least one annular and a number of radial grooves — the latter, as previously indicated, of asymmetrical cross-section — a slight additional rotary momentum is imparted to the armature in the course of its longitudinal displacement, thus assisting the rotary motion already referred to.

The invention will now be explained in more detail with reference to an embodiment thereof illustrated in the drawings, in which:

Fig. 1 is a diagrammatic longitudinal cross-

sectional view of a valve according to the invention;

Fig. 2 is a cross-sectional view, on an enlarged scale, of the armature's and the yoke's end faces which in operation contact each other;

Fig. 3 is a plan view of the contacting end face of the armature; and

Fig. 4 is a transverse view in the direction of the arrows *a-b* of a detail in Fig. 3.

The closing element of the valve is a ball 1 located in a valve seat 2 and biased thereonto by the force of a spring 3. The reference numeral 4 denotes a hydraulic fluid — oil in the embodiment illustrated — inlet communicating with a pressure chamber 5. Downstream thereof is a pressure chamber 6 communicating with a hydraulic oil outlet 7.

The valve-closing ball 1 is arranged to be moved off its seat by an intermediate member 8 fitted to an actuator rod 9. The latter is fastened to an end face of a roller-shaped magnet armature 10.

The space around the actuator rod 9 and the armature 10 is pressurized by the hydraulic oil fed through the inlet 4 and hence through a duct 11 to said space.

A tubular guide for the armature 10 comprises a soft iron end portion 12, a mid-portion 13 of non-magnetizable stainless steel and a further soft iron end portion 14. These portions are surrounded by a magnetizing coil 15.

A plug-shaped magnet yoke 16 having a bore for the passage of the rod 9 therethrough is located inside the portion 14. The magnetic shunt is effected by a soft iron tube 17 surrounding the coil 15. The reference numeral 18 denotes a seal secured by a screwcap 19.

Non-magnetic balls 20 and 21 project beyond the peripheral surface of the armature 10. They are accommodated in individual pouches extending inwardly from said surface. The reference numeral 22 in Fig. 2 denotes such a pouch. The portions 12, 13 and 14 of the guide are joined by electron beam welding as indicated by the reference numerals 23 and 24. As may also be seen from Fig. 2, the end face of the armature 10 closest to the yoke 16 is provided with radial grooves 25 and at least one annular groove 26. A flat ring 27 of a non-magnetic material is fastened to the opposite end face of the yoke 16 and serves, together with the grooves 25 and 26, to prevent, or at least to inhibit, the armature 10 from sticking to the yoke 16. As may be seen from Fig. 4, which is a transverse view along the line *a—b* of Fig. 3, the grooves 25 are asymmetrical in cross-section, the configuration in the embodiment illustrated being that of a right-angled triangle.

The method of operation of the valve will easily be understood. When the coil 15 is energized, a magnetic field is produced which starting from the portion 12 extends into the armature 10 and passes across the yoke 16, the portion 14 and the shunt tube 17 back into the portion 12. As a result, a high attractive force is produced between the armature 10 and the yoke 16. This force causes the armature 10 to be displaced towards the yoke 16 and thus to move, by means of its actuating elements 8 and 9, the valve ball 1 off its seat 2.

As can be seen in Figs. 1 and 2, the balls projecting beyond the peripheral surface of the armature 10 take up only a minimal part of the overall area thereof. Thus, a maximal transfer area is available for the magnetic flux starting from the portion 12 and extending into the armature 10. This produces, in relation to the size of the complete electromagnetic unit, a maximal actuating force. It is not essential for the balls to be arranged in transverse planes of the armature 10 as shown in Fig. 2. They may, alternatively, be arranged in axially extending rows. The total number of balls required is determined only by what, in practice, is ascertained to be necessary for guiding the armature. The only purpose of the balls is to provide for the hydraulic oil an accurately defined permanent flow gap between the portions 12 and 13, on the one hand, and the armature 10, on the other hand. Such an accurately defined flow gap is of particular importance in the case of the high pressures, for example 630 bar, for which a valve according to the invention is to be used.

The material of which the balls 20 and 21 are made may be magnetizable or not. A disadvantage of balls of magnetizable material is that the magnetic flux passes through them. This causes the balls arranged on one side of the armature 10 to stick to the tubular guide which is detrimental for the efficient operation of the armature. There is no such disadvantage in the case of non-magnetizable balls.

When the armature 10 is displaced in the direction towards the yoke 16 the hydraulic oil in the operating gap between them is removed therefrom in the direction towards the portion 12. As a result, a slight rotary momentum is imparted via the radial grooves 25 to the armature 10. This is assisted by virtue of the fact that the grooves 25 do not extend exactly radially towards the axis of rotation of the armature 10. However, experience has taught that a rotary momentum is produced even if the grooves extend exactly in radial direction.

CLAIMS

1. An electromagnetically operable valve including a roller-shaped magnet armature circumcirculated by a hydraulic fluid, the armature

a) being longitudinally displaceably mounted in a tubular guide which also serves as a support for a magnetizing coil,

b) being arranged to interact with a plug-shaped magnet yoke also disposed in the guide, and

c) carrying at its end face closest to the yoke an actuating member for a valve-closing element,

in which the armature is provided with spacedly

disposed pouches extending inwardly from its peripheral surface and each accommodating a single ball projecting beyond the peripheral surface and being arranged to slide, when the armature is operationally displaced in the guide, on the internal surface thereof.

2. A valve according to claim 1, in which the balls are magnetizable or non-magnetizable.

3. A valve according to claim 1 or claim 2, in which the guide comprises a mid-portion of non-magnetizable stainless steel surrounding the operating gap between the armature and the yoke, and two soft iron end portions respectively welded to the two end faces of the mid-portion.

4. A valve according to any of the preceding claims, in which the armature's and the yoke's end faces which in operation contact each other are provided with means for inhibiting the armature from sticking to the yoke.

5. A valve according to claim 4, in which the inhibiting means comprise a non-magnetic flat ring arranged on the end face of the yoke and at least one annular and a number of, at least substantially, radial grooves in the end face of the armature, and in which the cross-section of the radial grooves is asymmetrical.

6. An electromagnetically operable valve including a roller-shaped magnet armature circumcirculated by a hydraulic fluid, constructed, arranged and adapted to operate substantially as herein described with reference to the accompanying illustrative drawings.

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